World Academy of Science, Engineering and Technology
International Journal of Mechanical and Mechatronics Engineering
Vol:15, No:10, 2021

Vibration Absorption Strategy for Multi-Frequency Excitation

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Abstract : Since the early introduction by Ormondroyd and Den Hartog, vibration absorber (VA) has become one of the most commonly used vibration mitigation strategies. The strategy is most effective for a primary plant subjected to a single frequency excitation. For continuous systems, notable advances in vibration absorption in the multi-frequency system were made. However, the efficacy of the VA strategy for systems under multi-frequency excitation is not well understood. For example, for an N degrees-of-freedom (DOF) primary-absorber system, there are N 'peak' frequencies of large amplitude vibration per every new excitation frequency. In general, the usable range for vibration absorption can be greatly reduced as a result. Frequency modulated harmonic excitation is a commonly seen multi-frequency excitation example: $f(t) = \cos(\varpi(t)t)$ where $\varpi(t)=\omega(1+\alpha \sin(\delta t))$. It is known that f(t) has a series expansion given by the Bessel function of the first kind, which implies an infinity of forcing frequencies in the frequency modulated harmonic excitation. For an SDOF system of natural frequency ω_n subjected to f(t), it can be shown that amplitude peaks emerge at $\omega_{(p,k)}=(\omega_n \pm 2k\delta)/(\alpha \mp 1), k\in Z$; i.e., there is an infinity of resonant frequencies $\omega_{(p,k)}$, $k\in Z$, making the use of VA strategy ineffective. In this work, we propose an absorber frequency placement strategy for SDOF vibration systems subjected to frequency-modulated excitation. An SDOF linear mass-spring system coupled to lateral absorber systems is used to demonstrate the ideas. Although the mechanical components are linear, the governing equations for the coupled system are nonlinear. We show using N identical absorbers, for N ▯ 1, that (a) there is a cluster of N+1 natural frequencies around every natural absorber frequency, and (b) the absorber frequencies can be moved away from the plant's resonance frequency (ω_0) as N increases. Moreover, we also show the bandwidth of the VA performance increases with N. The derivations of the clustering and bandwidth widening effect will be given, and the superiority of the proposed strategy will be demonstrated via numerical experiments.

Keywords : Bessel function, bandwidth, frequency modulated excitation, vibration absorber
Conference Title : ICDSCD 2021 : International Conference on Dynamical Systems, Control and Design
Conference Location : Beijing, China
Conference Dates : October 04-05, 2021